ANNUAL REPORT

UNDERSTANDING AND SIMULATION OF THE EFFECTS OF VEGETATION ON NORTH AMERICAN MONSOON PRECIPITATION

NOAA GAPP/PACS Project (NA03OAR4310076)

Principal Investigator: **Zong-Liang Yang**

Institution:

Department of Geological Sciences
The University of Texas at Austin
Austin TX 78712
E-mail: liang@mail.utexas.edu
phone: (512) 471-3824; fax: (512) 471-9425

Date: **April 3, 2005**

ANNUAL REPORT

Understanding and Simulation of the Effects of Vegetation on North American Monsoon Precipitation

NOAA Award No. NA03OAR4310076

Principal Investigator: **Zong-Liang Yang**
Institution: **University of Texas at Austin**

The North American monsoon system (NAMS) provides an important water resource to the arid/semi-arid southwest U.S. and variations in its strength have social and economic implications. The overall goal of this project is to study the effects of vegetation growth on NAMS precipitation by using a regional coupled land-surface and meteorological model.

Over the past nine months, we have made progress in two complementary areas, as follows.

1. Study on the impacts of vegetation growth on NAMS development

This study has examined the impacts of vegetation growth on the development of NAMS by using the newly-released Weather Research and Forecasting (WRF) model version 2.02 coupled with different land schemes. To represent the vegetation growth, we have incorporated an interactive vegetation canopy (IVC) scheme into the NOAH land surface model in WRF. The IVC scheme calculates the vegetation carbon budgets, such as carbon assimilation and its allocation to leaf, stem, root, and wood. The scheme predicts the leaf area index (LAI), which is then converted to the fractional green vegetation cover (Fveg), which is a variable used by NOAH to determine transpiration from vegetated surfaces.

We have run five four-month-long experiments (from June 1 to August 31 of 2002) by using WRF with different land surface schemes. The first experiment uses SLAB, in which soil temperature is predicted, soil moisture is prescribed, but there is no explicit vegetation. The second experiment uses NOAH, in which both soil temperature and soil moisture are predicted but Fveg is prescribed. The third experiment uses NOAH/SWF, in which the root water uptake factor is modified to be a step function instead of a linear function of soil moisture. The fourth experiment uses NOAH/IVC, in which the IVC scheme is linked to NOAH/SWF. The fifth experiment uses NOAH/IVCR, in which deeper roots are specified in NOAH/IVC.

The main conclusions are as follows:

1) The simulations of atmospheric circulation and rainfall are very sensitive to the representation of land surface processes. The SLAB model produces significantly different near-surface wind fields and surface water fluxes (ET) from those produced by NOAH. The SLAB model fails to simulate the monsoon rainfall in the entire modeling period.

2) The representation of the root water uptake factor (SWF) for controlling the stomatal resistance is critical to accurately simulate transpiration over vegetated surfaces. A new method to calculate SWF using soil water potential instead of volumetric soil moisture increases the soil

water availability and ET. It also improves the rainfall simulation in the southern NAMS region in August.

3) Implementing the dynamic vegetation module into WRF/NOAH produces greater ET and rainfall in the southern NAMS region and the Southern Great Plain (SGP), especially in August. Further validation of the simulated vegetation cover fraction against satellite products will be conducted. Additional plans are to assimilate satellite-derived vegetation cover in the dynamic vegetation module.

4) Increasing rooting depth does not increase ET and rainfall in this study because the deeper soil layer, which is initialized with the NCEP/NCAR Reanalysis, is even drier than its upper layers. This experiment indicates a more accurate initialization of soil moisture or a longer period of integration may be required.
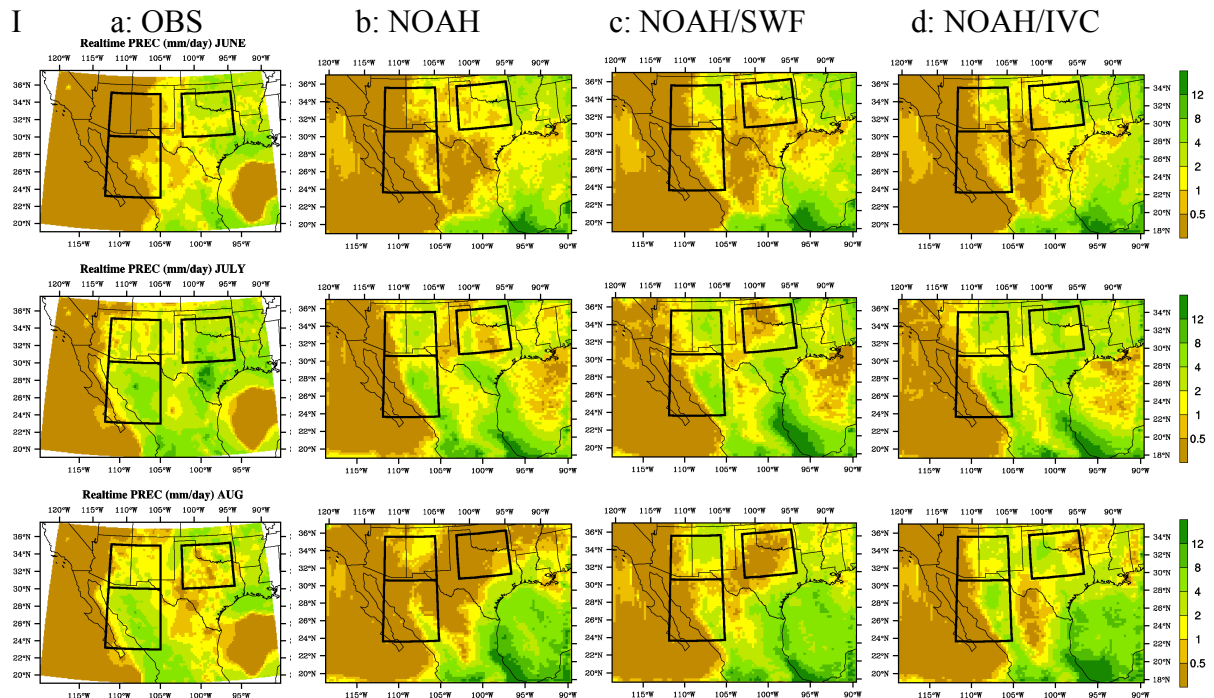

Figure 1 (a) The observed monthly rainfall (mm/day) for June, July, and August, (b) monthly rainfall from WRF coupled with NOAH, (c) monthly rainfall from WRF coupled with NOAH, but the root water uptake factor is modified according to the method described in the text, and (d) monthly rainfall from WRF with NOAH but both SWF and IVC are included.

2. A new runoff scheme for land-surface modeling

An accurate simulation of the water cycle in the NAMS region depends not only on the representation of vegetation growth, but also on many other processes. One such process is the topographic control on soil moisture distribution and runoff production. Although topographic based runoff models (TOPMODELs) have been available in the hydrologic community for over two decades, it remains unclear how to effectively incorporate TOPMODEL into land-surface models for monsoon studies. Here we use the NCAR Community Land Model (CLM) as an example to develop a strategy for incorporating a simplified TOPMODEL (SIMTOP).

In our approach, both surface runoff and subsurface runoff are parameterized as exponential functions of the grid-mean water table depth. Instead of a three-parameter gamma distribution function that is commonly used for computing the surface fractional saturated area, we use an exponential function to fit the actual distribution of the topographic index for a grid cell. In this method, the exponential function is used to scale down from the maximum fractional saturated area, F_{max}, which is defined as the ratio of the number of pixels with their topographic index larger than the grid-mean value to the number of total pixels in the grid-cell. It is shown that the exponential function outperforms the three-parameter gamma distribution function in mountainous regions while preserving the accuracy in relatively flat regions. In the case of baseflow, an exponential function is used to scale down from the maximum baseflow, $R_{b,max}$, which is taken as a calibration parameter in SIMTOP to avoid difficulties in determining the saturated hydraulic conductivity in the lateral direction and potential errors associated with computing the topographic index from coarse resolution digital elevation models.

SIMTOP has been validated against the observed runoff data for a small watershed and global continents. The baseline CLM overestimates runoff in the monsoon regions. However, the modified CLM that incorporates SIMTOP improves the simulations of runoff over the NAMS and other monsoon regions.
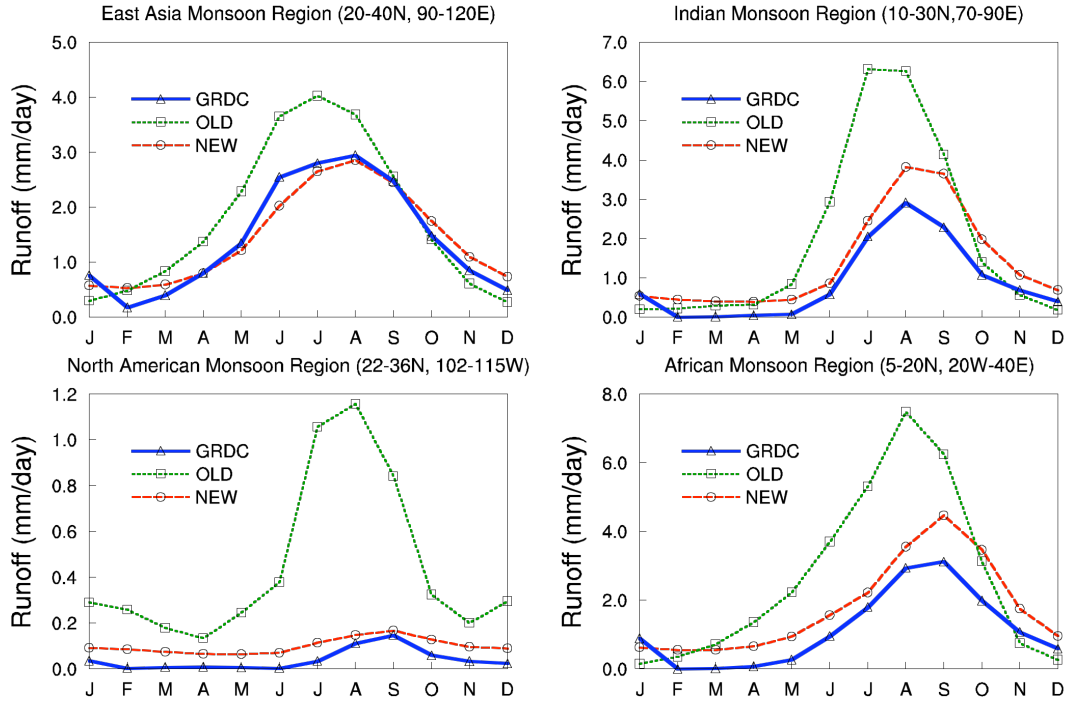
Figure 2. Simulated runoff from SIMPTOP (NEW) and from the baseline runoff scheme in the NCAR CLM (OLD) is compared to the GRDC (Global Runoff Data Center) runoff in four main monsoon regions.

3. Peer-reviewed journal publications

Knebl, M.R., Z.-L. Yang, K. Hutchison, and D.R. Maidment, 2005: Regional scale flood modeling using NEXRAD rainfall, GIS, and HEC-HMS/RAS: A case study for the San Antonio River Basin summer 2002 storm event, *Journal of Environmental Management* (in press).

Niu, G.-Y., Z.-L. Yang, and R. E. Dickinson, 2005: A simplified TOPMODEL for hydrologic simulations in a climate model as applied to the CLM (submitted to JGR).

Xia, Y., Z.-L. Yang, C. Jackson, P.L. Stoffa, and M.K. Sen, 2004: Impacts of data length on optimal parameter and uncertainty estimation of a land surface model, *Journal of Geophysical Research,* **109**, D07101, doi:10.1029/2003JD004419.

Xia, Y., Z.-L. Yang, P.L. Stoffa, and M.K. Sen, 2005a: Optimal parameter and uncertainty estimation of a land surface model: Sensitivity to parameter ranges and model complexities, *Advances in Atmospheric Sciences*, **22 (1)**, 142-157.

Xia, Y., Z.-L. Yang, P.L. Stoffa, and M.K. Sen, 2005b: Using different hydrologic variables to assess the impacts of forcing errors on optimization and uncertainty analysis of a land surface model at a cold catchment, *Journal of Geophysical Research*, **110**, D01101, doi:10.1029/2004JD005130.

4. Conference presentations

Yang, Z.-L. and G.-Y. Niu, 2004: The impacts of vegetation growth on the development of the North American monsoon system (NAMS), *EOS, Trans. AGU, Fall Meet., Suppl.,* 85, 2004, page F239.

Yang. Z.-L., G.-Y. Niu, and R. E. Dickinson**,** 2005: Modeling surface and subsurface runoff in CLM, NCAR LMWG Meeting, Boulder, CO., March 14, 2005.